Center for Independent Experts (CIE) Independent Peer Review of Recruitment Processes Alliance Research in the Southeastern Bering Sea

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Executive Summary

This review focuses on research by the Recruitment Processes Alliance (RPA), which is a partnership between a group of research programs operating in the eastern Bering Sea (EBS). The primary goal of the RPA is to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. The RPA undertakes seasonal field surveys in the south eastern Bering Sea, notably a spring larval survey and a late summer juvenile survey, as well as associated process studies and ecological modelling. This review focuses on design of the two primary surveys, on the use of data and understanding from these surveys and from RPA research in ecosystem models, and on the overall impact of the research on management of fisheries in the EBS, from an ecosystem perspective.

Key findings are as follows. The RPA has made impressive progress in understanding the dynamics of early life history processes in the EBS, particularly for walleye pollock. This has resulted in a large number of scientific publications in peer reviewed journals and the two primary surveys that are the focus of this review have been instrumental in making these scientific advances possible. Modelling has also been important in synthesizing understanding and a variety of biophysical models has been developed. Again, the surveys have been important to a number of these modelling efforts, though some are still a work in progress. The impacts of the research on fishery management in the EBS are harder to substantiate. Survey data are not currently used in a tactical sense, for example as input time series to stock assessment models. It seems unlikely that there would be benefits in doing so. Findings from RPA research are included in the annual stock assessment report, and anecdotal evidence suggests that this additional information can at times be influential. Broader findings from RPA research also find a prominent place in the Ecosystem Considerations chapter of the annual fishery reports. It is likely that the main longer term benefit of the research will be in helping to design management systems that are robust to future changes in ecological conditions in the EBS driven by climate change and variability.

The review includes recommendations in several key areas relating to the terms of reference. The review endorses the approach taken in the two primary RPA surveys, but suggests some improvements to each survey, in both cases adding an adaptive sampling component to the design, and for the late summer survey suggesting a greater focus on deriving acoustic estimates of larval and euphausiid abundance. Research in the EBS includes the use of a wide range of ecological models, only one of which, FEAST, was discussed in any detail in the review. This model will likely require some modification to make it suitable for management strategy evaluation (MSE), one of its stated purposes. MSE analyses, using FEAST and other models, would help to improve the management relevance and impact of the RPA research, and would also help identify critical knowledge gaps and inform survey designs. An example, related to one of the terms of reference in the review concerning salmon bycatch management in the pollock fishery, would involve assessing the benefits and costs of a further survey dedicated to determining a leading indicator of salmon abundance. Other recommendations and suggestions are documented in the body of the report and in the final section on Conclusions and Recommendations.

Background

The Alaska Fisheries Science Center (AFSC) conducts research on a wide variety of topics in support of fisheries management in the Eastern Bering Sea, the Aleutian Islands, and the Gulf of Alaska. Ecosystem and fisheries research has been conducted by various programs within the AFSC for over 30 years. Recently, several of these programs came together to form the Recruitment Processes Alliance (RPA), which joins expertise, merges effort, and facilitates scientific exchange in the study of Arctic and North Pacific ecosystem functioning. The RPA is a partnership between the Recruitment Processes program (the Ecosystems and Fisheries Oceanography Coordinated Investigations or EcoFOCI), the Ecosystem Monitoring and Assessment (EMA) program (the Bering Arctic-Subarctic Integrated Survey or BASIS), the Marine Acoustics and Conservation Engineering (MACE) program, the Resource Ecology and Ecosystems Modeling (REEM) program, and the Resource Energetics and Costal Assessment (RECA) program, as well as the members of the EcoFOCI Program that reside at the Pacific Marine Environmental Laboratory (PMEL). This effort is a unique collaboration among NMFS programs within the AFSC and across-line offices (National Marine Fisheries Service and Oceanic and Atmospheric) with a primary goal to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. To accomplish this, seasonal (spring, summer, autumn) field surveys and process-oriented research are conducted to inform single-species, multi-species, and biophysical ecosystem models. Survey methods rely on gridded net tows and selected use of acoustics to collect target species, with concurrent oceanographic and environmental sampling to estimate biological and physical oceanographic structuring forces. The RPA builds on previous collaborative efforts in the AFSC focused on recruitment and ecosystem processes.

The focus of this review is on the research carried out by the RPA, focusing particularly on two of the seasonal surveys undertaken in the SE Bering Sea to measure and understand the processes affecting the first year of life of several important species in the ecosystem, and the relationship to physical and oceanographic factors that drive year class strength. In particular, the review focuses on design elements in the spring larval surveys and the late summer BASIS surveys undertaken by several groups in the RPA. The review also focuses on the ways in which the data and information from these surveys are analysed and used to inform ecosystem modelling and management processes and issues in the SE Bering Sea. An additional issue addressed is the need to inform bycatch management processes in the pollock fishery associated with incidental catches of Chinook salmon.

Role in the Review

I was one of four experts selected by the CIE for this review (see Appendix 3). I am a fishery scientist with a background in stock assessment, population and ecosystem modelling, and management strategy evaluation. For the past decade or so, the focus of my research has been in developing scientific tools to support ecosystem based fisheries management. My expertise does not lie in fisheries oceanography, recruitment processes, or field based survey methods, though I have some general knowledge of these areas. However, other members of the review panel had (collectively) extensive expertise in these areas. My particular role in the review was to focus on the potential uses of the data being collected through the RPA program, to inform models and management processes. However, as required by the CIE, I address all terms of reference in the following report.

Summary of Findings

My findings from the review are summarised against each of the following Terms of Reference.

1) Review background materials and documents that detail the ecosystem and fishery survey design and methods, and data analysis methods and results for:
    a. Joint walleye pollock, Pacific cod, and arrowtooth flounder surveys;
    b. Chinook salmon and chum salmon survey
    c. Joint bio-physical oceanographic survey component (ecosystem).

The background material provided was a set of published (or in press) scientific publications detailing research undertaken by various members of the RPA focusing on oceanographic, ecosystem and early life history processes in the Eastern Bering Sea (EBS) – see list of papers in "Background reading provided prior to the review meeting" in Appendix 1. Many of these papers were published in *Fisheries Oceanography* or *Deep Sea Research*. Collectively, they document an impressive body of knowledge arising from RPA research (and its precursors). Much of the focus is on the importance of climate and oceanographic forcing on population and community dynamics in the EBS ecosystem. For key species, particularly pollock, the focus is on drivers of growth and mortality in the first year of life, with a view to understanding critical phases and processes that go to determine year class strength. Other papers (and posters – see Appendix 1) focus on other species or on changes in the zooplankton or ichthyoplankton communities. Many of the analyses are empirical in nature, but several involve attempts to model the processes involved. A number of them develop and/or address hypotheses describing recruitment processes (Spatial Match-Mismatch, Oscillating Control, etc.).

A summary of the background material is that it provided a good overview of the scientific knowledge and progress made in recent years in understanding the ecosystem dynamics of the EBS, and in particular, of the importance of climate and environmental factors in driving year class strength for key commercial species such as pollock. Understanding the drivers of year class strength has been a challenge in fisheries research for over 100 years (Hjort 1914) and the RPA has made a better attempt to crack this problem than any other research group of which I am aware, though the goal itself still remains elusive. The background papers were less useful in addressing the specific terms of reference of the review related to survey design, though several of the papers described key survey methods as background information. The background papers also did not, in general, address the use of the information collected in ecosystem modelling or in addressing specific management needs. Understanding of these issues and of the role played by the RPA came mainly from the presentations made during the review workshop (see Appendix 1) and from questions arising during the presentations and subsequent discussions. These points are picked up in addressing the remaining terms of reference.

2) Evaluate the *historic*, spring and late summer ecosystem and fishery survey designs, methods, and analytical approaches including data preparations and quantitative analyses to estimate the

nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

Based on the material presented at the workshop, supplemented by the background material and posters, the RPA has made considerable progress in understanding the nutritional and behavioural ecology of walleye pollock and Pacific cod, and, to a lesser extent, some of the other commercial or important predatory species in the ecosystem, such as arrowtooth flounder. Both the spring and late summer surveys have been important in developing this understanding, with the spring survey focusing mainly on the behaviour and fate of larvae and the late summer survey on age-0 juveniles. The later survey has been particularly important in understanding the role of energy content and nutrition in setting the fish up for overwinter survival, supplemented by laboratory studies on energetics and diet. The fact that both surveys have spanned periods of both warmer and cooler conditions has helped greatly in elucidating key processes in the first year of life, again particularly for pollock, and the factors that may be driving subsequent year class strength (recruitment) to the fished population.

Focusing on pollock for the moment, an overall hypothesis has emerged that pollock year class strength is related to energy content of juveniles prior to winter, in turn related to the types of zooplankton prey available over the spring, summer and fall, in turn related to temperature conditions in the EBS. In brief, cooler conditions (later retreat of sea ice) result in a zooplankton community dominated by larger copepod species which have higher energy content and result in pre-winter juveniles with higher energy content and better ability to overwinter. This appears unrelated to overall seasonal productivity – in fact the abundance of juvenile pollock generally appears to be higher in warmer years. Both surveys have contributed to this understanding, importantly supplemented by laboratory studies. The spring larval surveys have also contributed to understanding of spawning dynamics (spawning occurs in late winter but the eggs and larvae are driven by currents that generate the observed spatial distribution of larvae in the spring surveys). An interesting feature of the studies presented was that for Pacific cod, which show a history of recruitment anomalies identical to pollock over a considerable period of time (only breaking down in recent years, which may be due to uncertainties about year class strength for recently recruited year classes), the explanation of year class strength does not appear to be related to energy content going into winter. The determinants of recruitment variability for cod seem less well understood. Both surveys have also contributed to understanding of predation ecology during the first year of life – both with regard to spatial and temporal overlap of larvae and juveniles with plankton prey fields, and also overlap with larval and juvenile predators.

The picture that emerges of key processes in first year of life, and possible determinants of year class strength, is complicated and not yet fully resolved. Duffy-Anderson et al. (2015) document changes over time in hypotheses about drivers of year class strength in pollock, highlighting remaining uncertainties and suggesting that much is still to be learned. However, it is hard to see that the generally impressive results to date could have been achieved at all without key information provided by both the spring and late summer surveys under consideration.

3) Evaluate the *planned change* in trawl survey design for the late summer survey design (surface trawl with midwater acoustics to oblique trawl with acoustics), methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional

and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

4) Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning the late summer survey from surface trawl with midwater acoustics to an oblique trawl survey, particularly regarding its potential to provide comparisons between historical and future nutritional and behavioral ecology of target species.

I address terms of reference 3 and 4 together. I address them briefly as I am not an expert in survey method or design. Much more detailed and useful responses to these two terms of reference will be provided by two of the other CIE reviewers –John Simmonds and Paul Fernandes. CIE reviewer Ken Drinkwater is also best placed to comment on the oceanographic aspects of the surveys.

As explained by Ed Farley, the late survey summer survey (BASIs survey) evolved out of a focus on salmon ecology, particularly juvenile salmon in their first year of life at sea. The focus was therefore on the upper part of the water column, and tended to be in shallower water close to the coast. Since 2008, the focus has shifted to (mainly) gadid species, also in their first year of life, with the survey sampling a mixture of oceanographic, plankton and juvenile fish abundance, using a combination of net and acoustic sampling. These late summer / early autumn surveys have been vital in helping to understand the importance of juvenile fish condition (energy content) for winter survival and subsequent recruitment success, and the relationship with warm and cold years and zooplankton composition, as discussed elsewhere in the review.

The RPA proposed change in the BASIS survey is to shift from surface trawl with mid-water acoustics to oblique tow trawl (covering the full water column) with acoustics. Discussion during the review focused on enhancing the benefit and use of the acoustic elements of the survey. The design that emerged from these discussions involved a continuous acoustic survey using transects corresponding to the current grid design, with target verification sampling at 40 to 70 stations, adaptively chosen to correspond to areas of higher acoustic backscatter and interest. These locations would be sampled using the combined net/optics system which allows for detailed target verification specific to the water column. Other aspects of the current BASIS survey relating to hydrographic and plankton sampling, as well as juvenile fish energy content and stomach analysis, would be retained. Issues not resolved during the workshop review included acoustic sampling of the upper meters of the water column.

It is difficult for this reviewer to assess the trade-offs, costs and benefits of these proposed changes to the survey design. Considerations include a break in the current time series of some (but only some) variables of interest, and logistic issues around cost, availability of key resources including staff, etc. The RPA and staff at the AFSC are best placed to evaluate and consider these trade-offs in detail. Clear benefits from the proposed changes include improved (future) time series of abundance (as well as spatial distribution) for pollock juveniles, other fish species of interest (Pacific cod?), and (importantly) euphausiids. Overall, it seems that these benefits could be realised without a substantial overall increase in cost, time at sea, or drain on critical resources.

5) Evaluate the potential of the spring and late summer ecosystem and fishery survey designs and analyses, or an alternative, to (i) be applied to coupled biophysical-individual based modeling and trophic modeling approaches currently in use, ii) resolving mechanistic linkages among ecosystem components, and (iii) be applied to management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management approach.

(i) A variety of ecological modelling approaches and tools are used to understand and help manage resources and ecosystems in the EBS. These models are of various types and serve different purposes. For example, some models focus specifically on provision of advice to underpin resource management. These include single species models used for stock assessment, such as that used to assess the status of the pollock resource and inform harvest levels for that resource (Ianelli et al. 2014). Scientists at AFSC have also started to develop multi-species versions of such models, such as CEATTLE (Holsman et al., in review). Other models have been developed primarily to help synthesize data and understanding about the dynamics of various parts of the ecosystem, rather than to inform management issues. These also span single species models, such as those developed to understand aspects of the early life history dynamics of pollock in the EBS, for example using bioenergetic or individual based modelling (IBM) approaches (Siddon et al. 2013). There are also models for synthesis and understanding that are multi-species or ecosystem focused, such as the ROMS-NPZ model. The FEAST model (Aydin et al. 2010) is built on this foundation and focuses on synthesis of understanding about the dynamics of three key fish species in the EBS – walleye pollock, Pacific cod and arrowtooth flounder, though also modelling some aspects of plankton ecology and dynamics and coupled to the hydrodynamic ROMS model. Although the FEAST model is highly complex and models a lot of ecological processes, it is also intended for use as an operating model to underpin management strategy evaluation for the EBS. Mention was also made of an Ecopath with Ecosim model that has been developed for the EBS, covering more components of the ecosystem than the FEAST model.

The FEAST model was the main ecological model described and discussed at the review meeting in relation to the overall purpose of the review. Documentation for this model is not yet available, but as described at the review meeting, FEAST does model spawning and egg dispersal, but then really focuses on processes from age 1 onwards, although the size dynamic modelling does overlap into the juvenile size range. There was some discussion at the meeting about modifying the model to better capture first year of life dynamic processes, including at the larval stage. It was not clear from the presentations just how the zooplankton dynamics are modelled in FEAST (they seem to be input from the NPZD model which was not described), but the zooplankton and ichthyoplankton data from the larval and BASIS surveys would be important either as input time series or for aspects of model verification. The feeding ecology in the model would also be informed by the stomach content data collected in the BASIS survey for juvenile gadids. As described by Ivonne Ortiz, the model does deal with bioenergetic and feeding aspects of growth in relation to zooplankton diet, including at the juvenile stage.

In summary, the FEAST model (including the coupled NPZD model) is informed both by data directly from the two surveys, and from expert input by other members of the RPA to inform parameterization of processes such as timing and size of egg hatching, and no doubt a range of other processes. In the absence of detailed descriptions of the FEAST model, it is difficult to evaluate the importance of the survey data in model construction, parameterization, and verification. The purpose of this review is not to evaluate this or other models, though a review of the FEAST model would seem timely and valuable. Such a review should include its potential role as a tool for management strategy evaluation as well as for synthesis of data and understanding about population and ecosystem dynamics in the EBS. Separate formulations of the model for these two quite different purposes may well be required.

(ii) Understanding mechanistic linkages between ecosystem components is a challenge for any ecosystem. For the EBS, it is arguably made more challenging by the high degree of variability in the physical environment, notably in the year to year variability in temperature and sea ice conditions affecting the SEBS. Viewed in another way though, the variability helps to generate insights into linkages by providing contrasting conditions under which relationships between ecosystem components can be observed and compared.

Key components of the two surveys that address this issue include the measurement of zooplankton abundance and species composition, measurement of distribution and abundance of larval and juvenile fish of interest, and (especially for the BASIS survey), measurement of diet and energy content of fish. It is fortuitous (or well planned!) that these observations have spanned periods of warmer and colder temperatures, resulting in strong year to year contrasts in ecological conditions which has enhanced understanding of relationships. One of the interesting features in this respect has been the potential importance of stanzas of warm and cold years over the past decade, compared with previous years of seemingly more random inter-annual changes in temperature conditions in the SEBS, including ice cover. As a suggestion, many of the recent analyses (and insights derived from them) have been based on trends over these recent stanzas of warm and cold years, also corresponding to the period covered by the RPA surveys. However, some time series (particularly physical but some biological and certainly time series for recruitment (of pollock and cod) from stock assessments) do extend back in time to periods where warm and cold periods varied at higher frequency. It would be interesting and informative to try to see whether the insights and understanding generated from examination of recent survey data are borne out by examination of earlier parts of the time series.

(iii) The spring and late summer surveys play a generally indirect role in management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management (EBFM) approach, with the impact mediated in most instances through analyses, syntheses and models. Nevertheless, the information and particularly the insights these surveys have provided about (for example) pollock recruitment, but also broader ecosystem changes (e.g. in zooplankton community structure) under climate variability, can be of value in a broader ecosystem approach to management of the EBS.

Taking as a starting point Jason Link's views about EBFM (outlined in Ihde and Townsend 2013), we might usefully distinguish an ecosystem approach to fisheries management (EAFM) from EBFM. The former occurs where ecosystem considerations enter directly into stock assessments and/or technical advice on TACs. According to Link, EBFM is more generally about understanding coupled ecological social systems and the trade-offs involved in meeting a broad range of ecological, economic and social objectives.

Considering EAFM, the current stock assessment for EBS pollock (Ianelli et al. 2014) and the resulting management advice are not directly affected by the RPA surveys. None of the RPA time series are fitted directly in the assessment model, and the information about temperature or other impacts on recruitment is not used to inform the assessment. Nevertheless, the assessment report does include a section describing latest understanding about environmental influences on recruitment, and there is also a section of the report on Ecosystem Considerations, including a subsection on "Ecosystem effects on the EBS pollock stock", which cites RPA research. It is also important to note that stock assessment scientists and RPA scientists have started to investigate the likely longer term impacts of climate change on pollock stock dynamics (Mueter et al. 2011), and have simulation tested alternatives to current harvest strategies to test robustness to changes in future recruitment due to climate (Ianelli et al. 2011). The latter study concludes that harvest strategies that track changing stock dynamics and allow for changes in reference points do perform better under climate change scenarios, without greatly compromising current performance or performance in a stationary environment. However, these strategies are assumed to detect broad changes in dynamics over time, and do not attempt to model or fit to environmental time series of factors forcing recruitment. Reviews elsewhere (Punt et al. 2014) suggest that attempts to include environmental forcing for recruitment in stock assessment advice are generally unlikely to improve management performance unless the recruitment predictions can achieve quite high levels of accuracy.

Considering the contribution of the RPA surveys and research to EBFM, the Ecosystem Considerations chapter in the SAFE report (Zador 2014) provides a very comprehensive set of information about environmental conditions and ecosystem dynamics, much of it informed both directly from time series from the RPA surveys, and more generally by research findings arising from these surveys. For example, the chapter includes an Eastern Bering Sea report card that presents time series of indicators such as ice retreat and euphausiid biomass. It also presents interpreted information on ecosystem trends, "hot topics", and more detailed interpretations of trends in indicators, including zooplankton time series derived from both RPA surveys, trends in biodiversity and other community level indicators, and much more. The value and impact of this information is difficult to determine, but comments at the review workshop from Dave Witherell, from the North Pacific Fisheries Management Council (NPFMC), indicated that the Ecosystem Considerations chapter is seen as a valuable resource by Council, and that Council staff use it as a ready reference of useful information for a variety of tasks and issues that arise in Council business.

Link noted the importance of assessing trade-offs in EBFM. Most decision making by NPFMC involves consideration of alternative courses of action and the trade-offs involved. I note here the potential value of ecosystem models designed to support management strategy evaluation (MSE), and the intention to use the FEAST model in the longer term for this type of analysis. However, the FEAST model has not yet reached the stage of development where it is being used for this more strategic purpose, and as noted earlier in this report, there are design aspects that will need to be considered in making this tool useful for MSE work as opposed to providing a synthesis of scientific understanding.

In summary, while the RPA surveys are very valuable in improving understanding of ecosystem dynamics in the SEBS, and in helping to understand drivers of recruitment in key species such as pollock, they are not currently of direct use in EAFM while perhaps being of more general use in EBFM, mostly through improving general understanding of the EBS by stakeholders and decision makers. I suspect the real value lies not in better informing short term tactical decision making, but in the longer term being better placed to respond to variations in environmental forcing and associated changes in ecosystem structure, related to climate variability and change. It is also important to note that the RPA is only one contribution made by AFSC science to informing EBFM, though an important one.

6) Evaluate the potential of the late summer ecosystem and fishery survey design and analysis, or an alternative, to incorporate these data in a western Alaska Chinook salmon the estimation of an ‘abundance based cap’ for prohibited species catch within the Bering Sea walleye pollock fishery in comparison to the proposed ‘abundance based cap’ using estimates of adult western Alaska Chinook salmon returns as proposed within the North Pacific Fishery Management Council.

As presented by Jim Ianelli at the review workshop, bycatch of salmon in the Bering Sea pollock fishery is a major issue for that fishery. This is despite the fact that the overall bycatch rates in the pollock fishery are very low. Nevertheless, the absolute levels are considerable due to the scale of the pollock fishery, and arise in the context of concerns about several salmon species and stocks, notably Canadian stocks of Chinook salmon in the Yukon River system. Bycatch of Chinook salmon in the pollock fishery increased from the early 2000s, peaking in 2007, and declining substantially since then. Ianelli and Stram (2015) present an analysis assessing the adult equivalent harvest rate from the fishery on the upper Yukon (Canadian) stocks, showing that the harvest rates peaked at just over 4% and have declined subsequently. However, given the conservation status of these stocks, management measures have been put in place to set absolute caps on bycatch, with incentive mechanisms in place to keep catches below this level (Stram and Ianelli 2015).

The ways in which the caps and incentives operate, and the details of proposals to change the caps as salmon abundance and stock status change, are complex and remain unclear to this reviewer. However, the presentation by Ed Farley on day three of the workshop made clear that caps could be reduced if the stock abundance fell below a threshold of 250,000 Chinook salmon, based on a stock complex from the Upper Yukon region. This abundance threshold would be based on post-season in-river adult return counts, and would revise the pollock bycatch cap for the following season. This raises two management issues. The response in the bycatch limit is lagged – it occurs only after the mortality has occurred, and potentially several years after, given the extended oceanic phase of the salmon life history. This raises a problem for salmon conservation. The second issue with a lagged response affects the pollock fishery more directly. This would occur if the reduction in the cap occurred at a time when recruitment to the salmon stocks had improved and bycatch rates were increasing.

Ed Farley put forward the suggestion of using a (revised) BASIS-type survey to provide a leading rather than lagged indicator of juvenile salmon abundance, which could be used instead of adult returns to revise caps and help address the two issues just mentioned. He presented evidence from Murphy et al. (2013) showing a reasonably strong correlation between Canadian-origin juvenile index and subsequent adult returns ($R^2 > 0.7$, but based on a limited number of years). He then went on to discuss various operational aspects of such a survey (noting that the original BASIS survey had focused on juvenile salmon, but had changed about 208 to focus more on age-0 pollock). Juvenile salmon are generally found inshore of the current BASIS survey, so a new survey design would likely be required, focusing on the north east Bering Sea (NEBS) and the inshore part of the SEBS.

The proposal for a late summer juvenile salmon-focused survey to provide a leading indicator for use in applying the bycatch cap looks promising but requires some further analysis. An MSE analysis would be the ideal way forward, focusing on the trade-offs between alternative uses of adult returns and a juvenile index coupled to a bycatch cap system. Performance indicators for the MSE would include costs of alternative designs for a juvenile survey, outcomes for salmon protection, and outcomes for the pollock fishery, particularly with regard to constraints on the fishery resulting from difficulties arising from the second issue with the current lagged response, mentioned above. I note that some modelling has been done to consider the effects of current caps and incentive schemes, but it is not clear how easy it would be to extend this model to serve as an operating model for the MSE analysis just outlined. Mention was also made of a "salmon FEAST model", but it is not clear of the stage of development of this model. However, as the salmon bycatch issue seems to be a high priority for both fisheries, the investment in resources to consider undertaking such an MSE seems worth considering.

Although not part of the terms of reference for the present review, I can't help noting some other potential problems with the current salmon bycatch management arrangements and use of caps. Current debates seem to be about reducing caps as salmon abundance declines, which makes sense, but consideration should also be given to raising caps if and when salmon abundance increases. A fixed cap for all stock sizes above 250,000 would imply having to reduce bycatch rates substantially as salmon stocks recover, and this could rapidly become constraining on the pollock fishery. The design of alternative bycatch strategies that took account of this issue could also be part of a wider MSE analysis, as outlined above.

7) Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:
    a. separate Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling
    b. joint Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling, particularly regarding their potentials to: i) evaluate the nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species; ii) put that information into the context of their biotic and abiotic environments; and iii) characterize their roles in the eastern Bering Sea Ecosystem. Provide specific recommendations for short- and long-term improvements to anticipated compromises associated with spring and late summer ecosystem surveys.

My understanding from the presentations at the review workshop is that there is considerable spatial separation between juvenile Chinook salmon distributions (mainly inside the 50m isobath) and the distribution of larval and juvenile pollock (mostly outside the 50m isobath). There appears to be some further spatial separation of pollock with cod and (particularly) with arrowtooth flounder larvae and juveniles, although the spatial overlap of these with Pollock is greater than that of pollock with juvenile Chinook salmon.

If the primary focus for groundfish remains pollock, then the current spring and late summer surveys are appropriate for continuing these time series, noting two important variations. The first is the suggested change to the late summer BASIS surveys, detailed above in response to terms of reference 3 and 4. The second is the recommendation to add an adaptive component to the spring larval survey, retaining the current grid but adaptively extending it eastward (inshore) and to some extent northward if the survey transects do not appear to be sampling the spatial extent of the distribution of pollock larvae in a particular year. The ecosystem sampling (zooplankton, etc.) for both surveys should be retained.

From information presented at the meeting, a single late summer survey for both pollock and salmon would not be possible as the Oscar Dyson could not sample inshore sufficiently to cover the salmon distribution. A chartered smaller vessel will be required to undertake a salmon survey, which (as discussed above) should also cover areas north of 60 degrees, outside the range of the current BASIS survey.

Information was not provided sufficient for this reviewer to be able to determine the costs and logistic requirements of undertaking separate late summer surveys for both groundfish species and for salmon. However, the impression I gained from the discussion at the meeting was that the salmon surveys would appear to be a higher priority for the NPFMC, assuming they can deliver a suitable leading indicator abundance estimate as discussed under term of reference 6. Thus, such surveys may have to be conducted (at least initially) on an annual basis, while the current BASIS survey could be conducted every second year.

8) Evaluate gaps and inconsistencies in process research, particularly regarding the potential of research practices to provide mechanistic information to Integrated Ecosystem Assessments and Ecosystem Based Fishery Management practices.

There will always be gaps in process research to understand something as complicated as the dynamics of an ecosystem. Based on the material reviewed, the understanding of process and dynamics built up for this system exceeds that for most ecosystems globally. This statement needs to be qualified to the extent that the focus in this review has been on surveys that deliver information about physical and biological oceanography, and on processes focusing on the first year of life for groundfish (and to a lesser extent salmon in their oceanic phase) species. The focus did not include the extensive summer groundfish trawl and acoustic surveys undertaken annually, nor did it include any research on higher elements in the food chain, including marine mammals and seabirds. We did not therefore get a comprehensive view of ecosystem oriented research in the EBS nor an overall synthesis of its findings.

Given the primary focus in the review on process understanding about factors influencing year class strength in pollock, several gaps were noted. The existing surveys reviewed span a period from about May to October, or half of the year. Process understanding for the other half of the year is much more sparse, and is mostly inferred rather than directly observed. For example, much of the research presented on determinants of year class strength for pollock points to the importance of energy content in late autumn that likely determines overwinter mortality. There was some discussion about the possibility of sampling age 0 / age 1 pollock in late winter from industry vessels targeting the roe fishery. This might help elucidate information about the energetics of overwintering, and at what time in the overwinter period critical mortality sets in. While this may be of scientific interest, it is not obvious that it would contribute greatly to improvements in EBFM for the region. The potentially important role of ice algae in zooplankton nutrition was also mentioned as a gap in understanding of overwintering processes. Study of this process could perhaps be of longer term benefit for EBFM as it could contribute to better understanding of the possible impacts of long term ocean warming.

One approach to examine gaps in process understanding more systematically would be to evaluate key sources of uncertainty in ecosystem models that synthesize existing process understanding about (in this case) lower trophic level dynamics (including ichthyoplankton). Of the models examined in this review, the FEAST model seems to be the most comprehensive in focusing on the processes at the heart of the RPA research initiative, though noting that it does not (yet) deal well with larval fish processes. Models are useful tools not only for synthesizing existing data and understanding, but also for identifying critical uncertainties. In the context of contributing to EBFM, they are even more useful if used in MSE mode to evaluate management issues and trade-offs. It was stated during the review that the FEAST model was intended for this purpose, but has not yet been applied in this way. As I noted above, it may need some modification and simplification to be really useful in an MSE role. However, if it could be used in this role, it would be an ideal tool to help identify critical gaps in process understanding that are important to successful implementation of EBFM.

Conclusions and Recommendations

The stated primary goal of the Recruitment Processes Alliance (RPA) is to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. Viewed as a scientific objective, the RPA has made impressive progress towards this goal, particularly for walleye pollock in the (south) east Bering Sea. Progress has involved a synthesis of understanding from climate forcing, oceanography, phytoplankton and zooplankton dynamics, and fish energetics and early life history. It has also involved a coordinated program of field sampling over an extended period of time, supplemented with laboratory analyses and modelling. Much of the progress in understanding has come from the ability to observe the early life history dynamics over periods of time with strong variations in climate forcing and resulting changes in (particularly) zooplankton dynamics. The majority of the background papers and presentations focused on pollock, but some progress has also been made with other species of interest. The focus on salmon in this review was, however, set in the context of the need for a juvenile abundance index, rather than a focus on salmon dynamics per se.

While the scientific progress from the RPA program has been impressive, the impact on fisheries management in the EBS is less clear. This may be in part due to a lack of focus in the material provided on establishing this impact. The Ecosystem Considerations chapter (Zador 2014) clearly draws to some extent on data from RPA surveys, and more obviously on information and understanding arising from research in the RPA program. However, only anecdotal evidence was supplied on the impacts of this information on fishery management issues. Salmon bycatch seems to be a current pressing management issue of vital interest to the pollock fishery, and the RPA BASIS survey offers some promise of addressing this issue, albeit a new form of the survey will have to be implemented. While the insights into environmental factors affecting year class strength are mentioned in the annual pollock assessment report, the factors themselves are not currently part of that assessment, which does not use data from the RPA surveys. In the opinion of this reviewer, there is no early prospect of the tactical use of such data in the assessment. The longer term benefit for management of the RPA recruitment research is more likely to lie in the evaluation of harvest strategies under future climate change, as already explored in some research that was not strictly part of the review (Ianelli et al. 2011). The RPA surveys and research do inform the development of some of the ecosystem models discussed in the review, most notably the FEAST model. This model will likely require some modification and simplification to be used for management strategy evaluation, which would help inform EBFM in the eastern Bering Sea. This is one important potential route of impact from RPA research to EBFM. The Ecosystem Considerations work is also likely to have both current and future impact, though of a more diffuse nature.

In reviewing the material and presentations for this review against the terms of reference, several recommendations have arisen. Some of these pertain directly to the terms of reference, and others, which may be thought of as suggestions rather than formal recommendations, have arisen as something of an aside to the formal review. These recommendations and suggestions are summarised briefly here, with more detail to be found in the summary of findings in the main body of the report (and in the case of recommendations on survey design, in the reports of other CIE reviewers). They are grouped around several focal areas.

Survey design

- A more adaptive design for the spring survey should be considered, ensuring better spatial coverage of larval pollock distributions across years, thus improving the consistency of time series of indicators of larval abundance.
- The late summer BASIS survey should focus on acoustic methods to assess abundance of juvenile fish as well as euphausiids. Verification sampling for acoustic targets should follow an adaptive design.
- A separate survey for juvenile salmon abundance should be considered, pending an analysis of the likely benefits of the use of such a leading indicator for salmon bycatch management, relative to the current use of abundance indices based on adult returns.

Ecosystem modelling

- A range of models has been developed in the EBS to help synthesize process understanding, assess resource status, and evaluate management options. These include single species models (such as those used for stock assessment), relatively simple multi-species models (such as CEATTLE), individual based models, coupled ROMS-NPZ models, FEAST, and whole of system models such as Ecosim. Different models are required for different purposes. The developers of the FEAST model should consider developing alternative versions for use in management strategy evaluation, as the complexity and run speed of the current model does not lend itself to use in MSE. The FEAST model also needs better documentation than currently exists.
- There is value in continuing to invest in a range of models for the EBS to suit a range of purposes, and there would be benefit in future external review of such models and of the overall strategy for model development in the EBS.

Improving management impact

- Much of the RPA program appears to have been driven “bottom up”, based on addressing interesting scientific challenges. This has been valuable as it has led to considerable scientific progress in understanding early life history dynamics and potentially understanding the factors driving variability in year class strength in important commercial species such as pollock. The main benefit arising from this understanding is likely to be in designing management systems that are robust to future climate change, and this should be a main focus for achieving management impact.

- A greater focus on MSE would help provide a "top down" focus to the RPA program, helping to identify critical gaps in information and understanding, assessing the costs and benefits of alternative survey designs, and providing the clearest route to management impact for the program.
- Although hard to quantify, the information compiled in the Ecosystem Considerations chapter does appear to be influential in addressing some of the management issues faced by the NPFMC. Consideration should be given to a more formal approach to quantifying this impact, through periodic and structured formal survey of stakeholders and decision makers.

Other suggestions

- Many of the recent analyses (and insights derived from them) have been based on trends over recent stanzas of warm and cold years, also corresponding to the period covered by the RPA surveys. However, some time series (particularly physical, but some biological, and certainly time series for recruitment of pollock and cod from stock assessments) do extend back in time to periods where warm and cold periods varied at higher frequency. It would be interesting and informative to try to see whether the insights and understanding generated from examination of recent survey data are borne out by examination of earlier parts of the time series.
- Although not part of the terms of reference for the present review, there are other potential problems with the current salmon bycatch management arrangements and use of caps. The present focuses on reducing caps as salmon abundance declines, which makes sense, but consideration should also be given to raising caps if and when salmon abundance increases. A fixed cap for all stock sizes above 250,000 would imply having to reduce bycatch rates substantially as salmon stocks recover, and this could rapidly become constraining on the pollock fishery. The design of alternative bycatch strategies that took account of this issue could also be part of a wider MSE analysis.

Comment on the review process

This reviewer would like to thank both the organizers and the participants in the review meeting held at the AFSC facility in Seattle. The logistical arrangements were seamless, the background material was timely and relevant, and the whole meeting was held in an atmosphere of open and friendly enquiry, which made participation a pleasure, and which facilitated delving into the issues of relevance.

Future reviews of this type could be improved (or at least made easier for the reviewers!) by organising the presentations more clearly around addressing the specific terms of reference. The ability to do so emerged through the dialogue and the questions arising from the presentations, but having presentations more clearly structured around the terms of reference might have speeded understanding of the context underlying them for the benefit of the reviewers. In addition, it was difficult to address terms of reference that called for analysis of costs and benefits of alternative survey designs, without providing information (particularly on costs) that would allow such analyses to be undertaken, and without more background context on the practical resource and logistic constraints involved.

Appendix 1: Bibliography of materials provided for the review

Background reading provided prior to the review meeting

Peer-Reviewed Publications

Selected Key Papers of the Recruitment Processes Alliance

Andrews, A. G, Strasburger, W.W., Farley, E.V., Murphy, J.M., and Coyle, K.O. In review. Effects of warm and cold climate conditions on capelin and Pacific herring in the eastern Bering Sea. In review. Deep Sea Research.

Bacheler NM, Ciannelli L, Bailey KM, Duffy-Anderson JT. 2010**.** Spatial and temporal patterns of walleye pollock (*Theragra chalcogramma*) spawning in the eastern Bering Sea inferred from egg and larval distributions. Fish Oceanogr 19:107–120.

Cooper, D.W. and Nichol, D. In review. Juvenile Northern Rock Sole spatial distribution and abundance are correlated in the eastern Bering Sea: spatially-dependent production linked to temperature. Fisheries Oceanography.

Coyle, K.O., Eisner, L.B., Mueter, F.J., Pinchuk, A.I., Janout, M.A., Cieciel, K.D., Farley, E.V., Andrews, A.G. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. Fish Oceanogr. 20: 139–156. .

Duffy-Anderson, J.T., Barbeaux, S., Farley, E., Heintz, R., Horne, J., Parker-Stetter, S., Petrik, C., Siddon, E., and Smart, T. 2015. A critical synthesis of the first year of life of walleye pollock (*Gadus chalcogrammus*) in the eastern Bering Sea and comments on implications for recruitment. *Deep Sea Research II: Topics in Oceanography*, *in press.* DOI: 10.1016/j.dsr2.2015.02.001.

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Farley EV, Murphy JM, Wing BW, Moss JH, Middleton A. 2005**.** Distribution, migration pathways, and size of western Alaska juvenile salmon along the eastern Bering Sea shelf. Alaska Fisheries Research Bulletin 11: 15–26.

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Heintz, R.A., Siddon, E.C., Farley, E.V., and Napp, J.M. 2013. Correlation between recruitment and fall condition of age-o pollock (*Theragra chalcogramma*) from the eastern Bering Sea under varying climate conditions. *Deep Sea Res. II*. 94: 150-156.

Heintz, R. A., and Vollenweider, J.J. 2010. Influence of size on the sources of energy consumed by overwintering walleye pollock (*Theragra chalcogramma*). *J. Exp. Mar. Biol. Ecol.* 393:43-50.

Hermann, A.J., G.A. Gibson, N.A. Bond, E.N. Curchitser, K. Hedstrom, W. Cheng, M. Wang, P.J. Stabeno, L. Eisner, and K.D. Cieciel, 2013. A multivariate analysis of observed and modeled biophysical variability on the Bering Sea shelf: Multidecadal hindcasts (1970-2009) and forecasts (2010-2040). Deep-Sea Res. II, 94, 121–139, doi: 10.1016/j.dsr2.2013.04.007**.**

Hermann, A. J., G. A. Gibson, N. A. Bond, E. N. Curchitser, K. Hedstrom, W. Cheng, M. Wang, E. D. Cokelet, P. J. Stabeno. In Revision**.** Projected future biophysical states of the Bering Sea. Submitted to Deep-Sea Research II.

Hunt, G.L., Coyle, K.O., Eisner, L., B., Farley, E.V., Heintz, R., Mueter, F., Napp, J., Overland, J.M., Ressler, P.H., Salo, S., Stabeno, P.J. 2011. Climate impacts on eastern Bering Sea food webs: a synthesis of new data and an assessment of the Oscillating Control Hypothesis. *ICES J. Mar. Sci.* 68: 1230-1243.

Ladd, C., Stabeno, P.J. 2012. Stratification on the eastern Bering Sea shelf revisited. Deep-Sea Research Part II 65-70:72-83. DOI: 10.1016/j.dsr2.2012.02.009.

Livingston PA, Aydin K, Boldt J, Ianelli J, Jurado-Molina J. 2005. A framework for ecosystem impacts assessment using an indicator approach. ICES Journal of Marine Science. 62: 592–597.

Levin P. S., Fogarty M. J., Murawski S. A., Fluharty D**.** Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. PLoS Biology 2009;7:e1000014*.*

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Megrey, B.A., Hollowed, A.B., Hare, S.R., Macklin, S.A., Stabeno, P.J. 1996. Contribution of FOCI research to forecast of year class strength of walleye pollock in the Shelikof Strait, Alaska. Fish. Oceanogr. 5 (S1), 189–203.

Mordy, C.W., E.D. Cokelet, C. Ladd, F.A. Menzia, P. Proctor, P.J. Stabeno, and E. Wisegarver. 2012. Net community production on the middle shelf of the Eastern Bering Sea. Deep-Sea Res. II, 65–70, 110–125, doi: 10.1016/j.dsr2.2012.02.012.

Moss, J.H., Beauchamp, D.A., Cross, A.D., Myers, K.W., Farley Jr., E.V., Murphy, J.M., Helle, J.H. 2005. Evidence for size-selective mortality after the first summer of ocean growth by pink salmon. Trans. Am. Fish. Soc. 134, 1313–1322.

Napp JM, Baier CT, Brodeur RD, Coyle KO, Shiga N, Mier K 2002. Interannual and decadal variability in zooplankton communities of the southeast Bering Sea shelf. Deep-Sea Res II 49:5991–6008.

Overland, J.E., M. Wang, K.R. Wood, D.B. Percival, and N.A. Bond. 2012. Recent Bering Sea warm and cold events in a 95-year context. Deep-Sea Res. II, 65–70, 6–13, doi: 10.1016/j.dsr2.2012.02.013.

Petrik, C., J.T. Duffy-Anderson, F.J. Mueter, K. Hedstrom, and E. Curchitser. 2014. Biophysical transport model suggests climate variability determines distribution of Walleye Pollock early life stages in the eastern Bering Sea through effects on spawning. *Progress in Oceanography*. http://dx.doi.org/10.1016/j.pocean.2014.06.004.

Sheffield Guy, L., J. Duffy-Anderson, A.C. Matarese, C.W. Mordy, J.M. Napp, and P.J. Stabeno. 2014. Understanding climate control of fisheries recruitment in the eastern Bering Sea: Long-term measurements and process studies. *Oceanography* 27(4): 90–103, http://dx.doi.org/10.5670/oceanog.2014.89.

Siddon, E.C., Kristiansen, T., Mueter, F.J., Holsman, K.K., Heintz, R.A., and Farley, E.V. 2013. Spatial Match-Mismatch between Juvenile Fish and Prey Provides a Mechanism for Recruitment Variability across Contrasting Climate Conditions in the Eastern Bering Sea. *PLOS One*. DOI: 10.1371/journal.pone.0084526.

Sigler, M., Stabeno, S., Eisner, L. Napp, J., Mueter, F. 2013. Spring and fall phytoplankton blooms in a productive subarctic ecosystem, the eastern Bering Sea, during 1995-2011. DOI: 10.1016/j.dsr2.2013.12.007.

Smart, T., J.T. Duffy-Anderson, and J. Horne. 2012. Alternating temperature states influence walleye pollock life stages in the southeastern Bering Sea. Marine Ecology Progress Series 455:257–267, http://dx.doi.org/10.3354/meps09619.

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Yasumiishi, E.M., Criddle, K.R., Hillgruber, N., Mueter, F.J., Helle, J.H. 2015. Chum salmon (*Oncorhynchus keta*) growth and temperature indices as indicators of the year-class strength of age-1 walleye pollock (*Gadus chalcogrammus*) in the eastern Bering Sea. Fisheries Oceanography doi:10.1111/fog.12108 (in press).

Zador, S. (Ed). 2014. Ecosystem Considerations. Anchorage, AK, North Pacific Fisheries Management Council, 2012. 230 pp.

Presentations

A series of Power Point presentations was made by key staff involved in the Recruitment Processes Alliance. The presentation titles are indicated in the Agenda for the meeting, outlined in Appendix 5.

Additional reading provided during the review meeting

Danielson, S., Eisner, L., Weingartner, T., Aagaard, K., 2011. Thermal and haline variability over the central Bering Sea shelf: Seasonal and interannual perspectives. Continental Shelf Research, 31:539-554.

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Tom Ihde & Howard Townsend. 2013. Interview with Jason Link: Champion for Ecosystem Science and Management, Fisheries, 38:8, 363-369.

Additional papers referenced in this review

Aydin, K. *et al.* 2010. Integrating data, fieldwork, and models into an ecosystem-level forecasting synthesis: the Forage-Euphausiid Abundance in Space and Time (FEAST) model of the Bering Sea Integrated Research Program. ICES CM 2010/L:21.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research. Rapports et Proce`s-Verbaux des Re´unions du Conseil Permanent International Pour L'Exploration de la Mer, 20: 1–228.

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Ianelli, J. *et al.* 2011. Evaluating management strategies for eastern Bering Sea walleye pollock (*Theragra chalcogramma*) in a changing environment. ICES Journal of Marine Science, 68: 1297-1304.

Ianelli, J *et al.* 2014. Assessment of the walleye pollock stock in the Eastern Bering Sea. NPFMC Bering Sea and Aleutian Islands SAFE.

Ianelli, J.N. and D.L. Stram 2015. Estimating impacts of the pollock fishery bycatch on western Alaska Chinook salmon. ICES Journal of Marine Science, 72: 1159-1172.

Mueter, F. *et al.* 2011. Expected declines in recruitment of walleye Pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. ICES Journal of Marine Science, 68: 1284-1296.

Murphy, J., Howard, K., L. Eisner, A. Andrews, W. Templin, C. Guthrie, K. Cox, and E. Farley. 2013. Linking abundance, distribution, and size of juvenile Yukon River Chinook salmon to survival in the Northern Bering Sea. N. Pac. Anad. Fish. Comm. Tech. Report 8:25-30.

Punt, A. *et al.* 2014. Fisheries management under climate and environmental uncertainty: control rules and performance simulation. ICES Journal of Marine Science, 71: 2208-2220.

Stram, D.L. and J.N. Ianelli 2015. Evaluating the efficacy of salmon bycatch measures using fishery-dependent data. ICES Journal of Marine Science, 72: 1173-1180.

Appendix 2: CIE Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem

Scope of Work and CIE Process: The National Marine Fisheries Service (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in Annex 1. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: We request an independent CIE review of the ecosystem and fisheries recruitment processes applied research conducted at the NMFS's Alaska Fisheries Science Center (AFSC). Ecosystem and fisheries research has been conducted by various programs within the AFSC for over 30 years. Recently several of these programs came together to form the Recruitment Processes Alliance (RPA), which joins expertise, merges effort, and facilitates scientific exchange in the study of Arctic and North Pacific ecosystem functioning. The RPA, comprised of the Recruitment Processes program (the Ecosystems and Fisheries Oceanography Coordinated Investigations or EcoFOCI), the Ecosystem Monitoring and Assessment (EMA) program (the Bering Arctic-Subarctic Integrated Survey or BASIS), the Marine Acoustics and Conservation Engineering (MACE) program, the Resource Ecology and Ecosystems Modeling (REEM) program, and the Resource Energetics and Coastal Assessment (RECA) program, as well as the members of the EcoFOCI Program that reside at the Pacific Marine Environmental Laboratory (PMEL). This effort is a unique collaboration among NMFS programs within the AFSC and across-line offices (National Marine Fisheries Service and Oceanic and Atmospheric) with a primary goal to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. To accomplish this, seasonal (spring, summer, autumn) field surveys and process-oriented research are conducted to inform single-species, multi-species, and biophysical ecosystem models. Survey methods rely on gridded net tows and selected use of acoustics to collect target species, with concurrent oceanographic and environmental sampling to estimate biological and physical oceanographic structuring forces. For this review, an impartial evaluation of the joint, RPA fisheries-oceanographic research of the Eastern Bering Sea will be conducted to evaluate the survey methodology and analytical approaches used to estimate relative abundance, distribution, biomass, and physiological condition of target species, the biophysical environmental variables thought to structure recruitment of target species, and the incorporation of observed variables into ecosystem forecast models, Integrated Ecosystem Assessments (IEAs), and Ecosystem Based Fishery Management (EBFM) practices. The terms of Reference (ToRs) of the peer review are attached in Annex 2.

Requirements for CIE Review:

Four CIE experts shall participate in a panel peer review in accordance with the SoW and ToRs herein. The review panel shall have the combined expertise and working knowledge in (1) recruitment processes surveys and design including fisheries-oceanographic plankton and trawl survey design, operation, sampling and analysis; (2) familiarity with ocean ecology of early life stages of groundfish and salmonid species, (3) field methods, including acoustics for process studies, and spatial sampling and analysis of distribution and abundance of young fish; (4) experience in Ecosystem Based Fishery management and/or Integrated Ecosystem Assessment; (5) climate-coupled single-species, multi-species, and biophysical models. Each CIE reviewer is requested to provide a separate and independent evaluation. The CIE reviewer's duties shall include (1) conducting pre-review preparations with document review; (2) participation in panel review meeting; and (3) completion of a CIE independent peer review report in accordance with the ToR and the Schedule of Milestones and Deliverables. The agenda for the Panel review meeting will be provided to reviewers along with background materials two weeks prior to the panel meeting. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location/Date of Peer Review: Four CIE experts shall participate during a panel review meeting scheduled at the AFSC in Seattle, Washington to be held during the dates of July 21-24, 2015.

Statement of Tasks: Each CIE expert shall complete the following tasks in accordance with the SoW, ToRs and Schedule of Milestones and Deliverables specified herein.

Prior to the Peer Review: Upon completion of the CIE expert selection by the CIE Steering committee, the CIE shall provide the CIE expert information (name, affiliation, and contact details) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to each CIE expert. The NMFS Project Contact is responsible for providing the CIE experts with the background documents, reports, foreign national security clearance, and information concerning other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE experts participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE experts who are non-US citizens. For this reason, the CIE experts shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website:

http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to each CIE expert all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance with the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Panel Review: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs. Modifications to the SoW and ToR cannot be made during the peer review, and any SoW or ToR modification prior to the peer review shall be approved by the COR and CIE Lead Coordinator. Each CIE expert shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their tasks shall be focused on the ToRs as specified in the contract SoW.

The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the Schedule of Milestones and Deliverables.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting in Seattle, Washington during 21-24 July 2015, and conduct an independent peer review in accordance with the ToRs (Annex 2);

3) No later than 7 August 2015, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to mshivlani@ntvifederal.com, and to Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas@miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

29 June 2015	CIE sends the reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
6 July 2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
21-24 July 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
7 August 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
21 August 2015	CIE submits the CIE independent peer review reports to the COTR
28 August 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This "Time and Materials" task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and the Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToR within the SoW as long as the role and ability of the CIE experts to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COR (Allen Shimada, via allen.shimada@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE reports shall have the format and content in accordance with Annex 1, (2) the CIE reports shall address each ToR as specified in Annex 2, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COR. The COR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

Support Personnel:

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Key Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. Each CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of each peer review report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

a. Reviewers should describe using their own words, the review activities completed during the panel review meeting, including a detailed summary of findings, conclusions, and recommendations.

b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

c. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

e. Each CIE independent peer review report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. Each CIE independent report shall be an independent peer review of each ToRs.

3. Each report shall include the appendices as follows:

Appendix 1: Bibliography of materials provided for review
Appendix 2: A copy of the CIE Statement of Work
Appendix 3: Panel Membership and other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Terms of Reference (ToR) for the Center for Independent Experts Panel Review of the Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem.

Each CIE reviewer will conduct an independent peer review addressing each ToR;

a. Review background materials and documents that detail the ecosystem and fishery survey design and methods, and data analysis methods and results for:
    a. Joint walleye pollock, Pacific cod, and arrowtooth flounder surveys;
    b. Chinook salmon and chum salmon survey
    c. Joint bio-physical oceanographic survey component (ecosystem).

b. Evaluate the *historic*, spring and late summer ecosystem and fishery survey designs, methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

c. Evaluate the *planned change* in trawl survey design for the late summer survey design (surface trawl with midwater acoustics to oblique trawl with acoustics), methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

d. Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning the late summer survey from surface trawl with midwater acoustics to an oblique trawl survey, particularly regarding its potential to provide comparisons between historical and future nutritional and behavioral ecology of target species.

e. Evaluate the potential of the spring and late summer ecosystem and fishery survey designs and analyses, or an alternative, to (i) be applied to coupled biophysical-individual based modeling and trophic modeling approaches currently in use, ii) resolving mechanistic linkages among ecosystem components, and (iii) be applied to management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management approach.

f. Evaluate the potential of the late summer ecosystem and fishery survey design and analysis, or an alternative, to incorporate these data in a western Alaska Chinook salmon the estimation of an 'abundance based cap' for prohibited species catch within the Bering Sea walleye pollock fishery in comparison to the proposed 'abundance based cap' using estimates of adult western Alaska Chinook salmon returns as proposed within the North Pacific Fishery Management Council.

g. Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:
    a. separate Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling

b. joint Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling, particularly regarding their potentials to: i) evaluate the nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species; ii) put that information into the context of their biotic and abiotic environments; and iii) characterize their roles in the eastern Bering Sea Ecosystem. Provide specific recommendations for short- and long-term improvements to anticipated compromises associated with spring and late summer ecosystem surveys.

h. Evaluate gaps and inconsistencies in process research, particularly regarding the potential of research practices to provide mechanistic information to Integrated Ecosystem Assessments and Ecosystem Based Fishery Management practices.

Appendix 3: Panel membership

Dr. John Simmonds
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Dr. Ken Drinkwater
Senior Scientist
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Email: ken.drinkwater@imr.no

Dr. Paul Fernandes

MASTS Reader in Fisheries Science
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Dr. Tony Smith

Chief Research Scientist
CSIRO Oceans and Atmosphere
Castray Esplanade
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Appendix 4: Attendance at the Review Meeting

Alaska Fisheries Science Center

Ed Farley, Ellen Yasumiishi, Ron Heintz, Lisa Eisner, Janet Duffy-Anderson, Phil Mundy, Jeff Napp, Martin Dorn, Mike Sigler, Jim Ianelli, Anne Hollowed, Ann Materese, Libby Logerwell, Stephanie Zador, Kerim Aydin, Chris Wilson, Alex De Robertis, Heather Tabisola, Steve Porter, Adam Spear, Samantha Zeman, Daniel Geldof, Adam Spear, Steve Porter, Morgan Busby

Pacific Marine Environmental Lab

Phyllis Stabeno, Carol Ladd, Calvin Mordy, Al Herman

Attendees from outside AFSC/PMEL

Lauri Sadorus, International Pacific Halibut Commission

Melissa Haltuch, Northwest Fisheries Science Center

David Witherell, North Pacific Fisheries Management Council

Keith Criddle, University of Alaska Fairbanks

Yvonne Ortiz, University of Washington

Elizabeth Siddon, NRC post doc

Nick Bond, Southwest Fisheries Science Center

Kelly Kearney, University of Washington

Appendix 5: Agenda for the Review Meeting

Tuesday, July 21 – Physics, Lower Trophic Dynamics, and Modeling
Hypothesis: Climate change and variability have predictable effects on the bottom-up and top-down mechanisms, which regulate fisheries recruitment in Alaska

Time	Event	Speaker(s)
8:30	Coffee, available at AFSC	
9:00	Welcome, Introduction, Terms of Reference, Charge to the Reviewers	M. Sigler
9:15	Overview: Ecosystem and process work in the context of the mission of NOAA Fisheries & AFSC; History: from BSIERP to the RPA; Motivation for research - overarching goals and priorities (Terms of Reference: ToR 1)	M. Sigler
9:45	SEBS Ecosystem Based Oceanography: Climate regimes, physical oceanography, sea ice dynamics & phenology, nutrients, and long-term monitoring (ToR 1)	P. Stabeno, C. Ladd
10:15	*Break*	
10:30	Lower Trophic Ecology: Mechanisms of influence of atmospheric, oceanic, nutrient effects on phytoplankton and zooplankton, current understanding, and key uncertainties (ToR 1)	L. Eisner, J. Napp
11:00	Lower Trophic Modeling: Forecasting and key variables (ToR 1)	K. Aydin
11:15	Physical Projection Modeling: Short-term and long-term (ToR 1)	A. Hermann, N. Bond
11:45	Open Discussion: Question and Answer (ToR 1)	M. Sigler, moderator
12:00	**Lunch** **Poster Session A**	
13:30	Historical and Current Oceanographic and Lower Trophic Sampling: FOCI (ToR 2)	J. Duffy-Anderson
14:00	Open Discussion: Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design (cost/benefits); Potential of research to identify mechanisms, increase understanding and inform modeling (ToR 2)	M. Sigler, moderator
15:00	*Break*	
15:15	Historical and Current Oceanographic and Lower Trophic Sampling: EMA (ToR 2)	E. Farley
15:45	Open Discussion: Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design	M. Sigler, moderator
16:45	End of Day	

Wednesday, July 22 – Groundfishes and Modeling

Hypothesis: The effects of climate and ecosystem function on fish recruitment are most evident during 2 critical periods: 1) early to late larval state when mortality is a function of growth and 2) the first winter when mortality is a function of size and energy stores

Time	**Event**	**Speaker(s)**
8:30	Coffee, available at AFSC	
9:00	Groundfishes: Ichthyoplankton Ecology (walleye pollock, Pacific cod, arrowtooth flounder). Description of spawning, eggs, larval, early juvenile ecology and key uncertainties; Mechanisms of influence of ocean physics and lower trophic on fish early life ecology (ToR 1)	J. Duffy-Anderson
9:30	Groundfishes: Juvenile Ecology (walleye pollock, Pacific cod, arrowtooth flounder). Description of juvenile ecology and key uncertainties; Mechanisms of influence of ocean physics and lower trophic on fish juvenile ecology (ToR 1)	E. Siddon
10:00	Pollock Condition and Recruitment Index (ToR 1)	R. Heintz
10:15	*Break*	
10:30	Trophic Modeling: Fish-Euphausiid Abundance in Space and Time (FEAST); Current conceptual model and parameter estimates (ToR 1)	J. Ortiz, K. Aydin
11:30	Open Discussion: Question and Answer (ToR 1)	
12:00	**Lunch** **Poster Session B**	
13:30	Ichthyoplankton Sampling: Historical spring groundfish early life stage sampling. Planned changes to support fish ecology questions and ecosystem modeling; Data, analyses, and products (ToR 5, 8)	J. Duffy-Anderson
14:00	Open Discussion of Ichthyoplankton Sampling. Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design (cost/benefits); Potential of research to identify mechanisms, increase understanding and inform modeling (ToR 5, 8)	M. Sigler, moderator
15:00	*Break*	
15:15	Juvenile Sampling: Historical summer juvenile groundfish sampling. Planned changes to support fish ecology questions and ecosystem modeling. Data, analyses, products (ToR 3, 4, 5, 8)	E. Farley
15:45	Open Discussion of Juvenile Sampling. Evaluation of historic methods, analytical approaches, data & quantitative analyses to estimate ecology of target species; Planned changes in survey design (cost/benefits); Potential of research to identify mechanisms, increase understanding and inform modeling. (ToR 3, 4, 5, 8)	M. Sigler, moderator
16:45	End of Day	

Thursday, July 23 - Ecosystem Based Fishery Management and Salmon Ecology and Modeling

Time	Event	Speaker(s)
8:30	Coffee, available at AFSC	
9:00	North Pacific Fisheries Management Council (NPFMC) and ecosystem-based scientific advice. What are the mandates to do EBFM, what are the leading issues in Alaska, and what are opportunities for providing actionable advice (ToR 1, 5, 8)	A. Hollowed
9:30	The NOAA Integrated Ecosystem Assessment (IEA) Program, the Bering Sea Ecosystem Plan, processes for how the AFSC conducts and operationalizes ecosystem science in management (ToR 1, 5, 8)	K. Aydin
10:00	*Break*	
10:15	The incorporation of ecosystem information into single-species stock assessments, multi-species stock assessments, and management strategy evaluations (MSEs) (ToR 1, 5, 8)	J. Ianelli
10:45	Ecosystem indicators and ecosystem assessments in the Alaska region (ToR 1, 5, 8)	S. Zador
11:15	RPA products developed or delivered for Alaska EFBM: Working Groups, Species Report Cards, and Indicators (ToR 1, 5, 8)	E. Yasumiishi
11:45	Open Discussion: Question and Answer	M. Sigler, moderator
12:00	**Lunch** **Poster Session C**	
13:30	Management of Salmon Resources (ToR 1)	J. Ianelli
14:00	Overview Chinook, Chum salmon: Description of early life ocean ecology and key uncertainties; Mechanisms of influence of ocean physics and lower trophic on fish early life ecology (ToR 1)	E. Farley
14:30	Trophic Modeling: Chinook FEAST. Current conceptual model and parameter estimates for chinook FEAST (ToR 6, 8)	K. Aydin, I. Ortiz, A. Hermann, K. Kearney
15:00	*Break*	
15:15	Historical and Current Salmon Sampling: Historical sampling, planned changes to support fish ecology questions and ecosystem modeling; Data, analyses, and products (ToR 6, 8)	E. Farley
15:45	Open Discussion: Evaluate trade-offs and cost/benefit of separating salmon and groundfish surveys; Conducting biennial sampling for the southeast Bering Sea; and improvements and/or caveats (ToR 7, 8)	M. Sigler, moderator
16:45	End of Day	

Friday, July 24 – Q&A and Wrap-up

Time	Event	Speaker(s)
8:30	Coffee, available at AFSC	
9:00	Q&A with Reviewers and Presenters: Ocean Physics, Lower Trophic, and Modeling	M. Sigler, moderator
10:00	Q&A with Reviewers and Presenters: Fish Species (Groundfishes, Salmonids) and Trophic Models	M. Sigler, moderator
11:00	Q&A with Reviewers and Presenters: Application to Ecosystem Based Fishery Management	M. Sigler, moderator
12:00	Closing Remarks	M. Sigler
12:15	**Lunch <<End of Public Review>>**	
13:30	Reviewers: Closed Session	Conference Room